MARK HARDY/STUDIO-8

DATE WITH HISTORY

BY EWEN CALLAWAY

By revamping radiocarbon dating, Tom Higham is painting a new picture of humans' arrival in Europe.

Beside a slab of trilobites, in a quiet corner of Britain's Oxford University Museum of Natural History, lies a collection of ochre-tinted human bones known as the Red Lady of Paviland. In 1823, palaeontologist William Buckland painstakingly removed the fossils from a cave in Wales, and discovered ivory rods, shell beads and other ornaments in the vicinity. He concluded that they belonged to a Roman-era witch or prostitute.

"He did a good job of excavating, but he interpreted it totally wrong," says Tom Higham, a 46-year-old archaeological scientist at the University of Oxford's Radiocarbon Accelerator Unit. Buckland's immediate successors did a little better. They determined that the Red Lady was in fact a man, and that the ornaments resembled those found at much older sites in continental Europe. Then, in the twentieth century, carbon dating found the bones to be about 22,000 years old[1] and, later, 30,000 years old[2] — even though much of Britain was encased in ice and seemingly uninhabitable for part of that time. When Higham eventually got the bones, his team came up with a more likely scenario: they were closer to 33,000 years old and one of the earliest examples of ceremonial burial in Western Europe.

"It is another sobering example of cocked-up dates," says Higham, whose laboratory is leading a revolution in radiocarbon dating. By developing techniques that strip ancient samples of impurities, he and his team have established more accurate ages for the remains from dozens of archaeological sites. In the process, Higham is rewriting European history for around 30,000–50,000 years ago — a time referred to as the Middle-to-Upper Palaeolithic transition — when the first modern-looking humans arrived from Africa and the last Neanderthals vanished. Higham thinks that better carbon dating will help to resolve debates about whether the two ever met, swapped ideas or even had sex. It might even explain why humans survived and Neanderthals did not.

"I admire him," says Paul Mellars, an archaeologist from the University of Cambridge, UK, and an expert on this period in Europe, for "the sheer doggedness and sense of vision" he has for improving radiocarbon dating of the Palaeolithic. That vision sometimes clashes with other scientists' views, but Higham makes no apologies for his interpretations as long as the dates are solid. "I want to know the truth" is something he says a lot.

A WOOLLY FIELD

If you Google 'archaeologist' and 'Higham', the first hit is likely to be Charles Higham, a 72-year-old professor who has charted the origins of agriculture and government in southeast Asia. Tom was born in Cambridge, where his father was based until 1966. Charles then moved the family and nine-month-old Tom to New Zealand's rugged south island to start an archaeology department at the University of Otago in Dunedin. As a teenager, Tom spent summers at Ban Na Di, a study site in northeastern Thailand, where his duties included helping with human excavations and brewing tea for the crew.

PEOPLING THE PLANET
Interactive map of migrations:
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Tom didn't originally plan to follow his father's path. As a child he was obsessed with the history of the American West. At university, he planned to study geography and glaciology, but switched to archaeology after excelling in an introductory course taught by his father that he had signed up for on a whim. But his enthusiasm soon waned. "I got less and less interested in archaeology because it was so subjective and woolly."

The reasons for that woolliness were partly technical and partly historical, dating back to before the Highams' time. Archaeology before carbon dating relied on two principles: older things are buried beneath younger things, and people with cultural ties make similar-looking objects, such as stone tools. But dates were hard to come by. In the early nineteenth century, the Danish historian Rasmus Nyerup wrote that most of early human history was "wrapped in a thick fog"[3]. "We know that it is older than Christendom," he wrote, "but whether by a couple of years or a couple of centuries or even by more than a millennium, we can do no more than guess."

The fog began to lift in the middle of the twentieth century, when US chemist Willard Libby and his colleagues[4] showed that all formerly living things bear a clock powered by radioactive carbon-14. Organisms incorporate tiny amounts of this isotope as they grow, and they maintain a constant ratio between it and other, non-radioactive, carbon isotopes throughout their lives. After death, the carbon-14 decays with a half-life of about 5,730 years, and the dwindling ratio serves as a time stamp. Libby's team proved the accuracy of this 'clock' on objects of known age, such as Egyptian mummy tombs, and bread from a house in Pompeii, Italy, that was burned during the eruption of Vesuvius. Libby earned the 1960 Nobel Prize in Chemistry for his work.

The clock gets less accurate as the samples age, however; cruelly, it begins to fail at one of the most interesting times of human history in Europe. Within 30,000 years, 98% of the already vanishingly small quantities of carbon-14 in bone is gone. And carbon-14 molecules from surrounding soil start to seep into the fossils. Collagen, the part of bone that contains the most carbon suitable for dating, sops up contaminants like a sponge, creating a false record. If just 2% of the carbon atoms are contemporary, then a 44,000-year-old bone will return a carbon date of 33,000 years old, Higham calculates.

Most of the thousands of carbon dates from archaeological sites from the Middle-to-Upper Palaeolithic era are wrong, say scientists, perhaps even as many as 90%. As a result, archaeologists can agree on the history of this era only in the broadest of brushstrokes.

Tom found himself drawn to the quantitative side of archaeology to help fill in those details. His father had counselled that if he wanted a future in the field, Tom ought to join the push to make it a more rigorous science, emphasizing testable theory, experiment and statistics. So, at his father's urging, Tom applied for and completed a PhD at the University of Waikato's Radiocarbon Dating Laboratory in Wellington, then did a postdoc there. And when a faculty position became available at a better-funded lab at the University of Oxford in 2000, he moved back to his birth country.

Any idea that archaeology hasn't gone in the direction that Charles predicted is dispelled by a visit to his son's workplace. Its centrepiece is a giant £2.5-million (US$4-million) particle accelerator, which is used to tot up the number of radioactive carbon molecules in a sample.

Similar machines have been used for carbon dating since the 1970s and have allowed scientists to date smaller samples with more precision than before. But they have also produced their share of erroneous dates. "People used to take bones, grind them up and date them, and you got all kinds of dates because no one bothered to check if there was collagen or not," says Ofer Bar-Yosef, an archaeologist at Harvard University in Cambridge, Massachusetts. And rather than damage valuable human bones or animal bones marked with cuts from stone tools, scientists tended to date fragments of unidentified animal bones found alongside human remains, assuming, not always correctly, that they coincided with human occupation. "It just breaks your heart to see what people have dated before. They've basically dated pieces of shit," Higham says.

His team didn't change the machine — the secret to more accurate dating lies in the rigorous way the samples are processed beforehand. The team typically starts with bones that are linked unequivocally with human occupation, such as cut-marked bones. To remove contaminants such as decayed organic matter from soils or even the glues used to assemble fossils, the researchers treat the bone with chemicals that tear collagen's triple helices into single chains to release the trapped contaminants. A molecular sieve then filters out contaminating carbon molecules, leaving behind pure collagen. The colour of the final product is a good indicator of its quality, Higham says, holding up a glass bottle containing a white, fluffy, grape-seed-size fleck that resembles cotton wool.

The Red Lady and remains from other sites in Britain were the first that his lab examined. He has since expanded his search across continental Europe, and in 2007 his team won a £350,000 grant from Britain's Natural Environment Research Council in Swindon to re-date three dozen archaeological sites. The number eventually ballooned to 65.

OLDER AND OLDER

Like the Red Lady, bones from many sites are turning out to be millennia older than previously thought. Before Higham's work, the oldest human bones in Europe were from the Peştera cu Oase cave in southwestern Romania, dated to around 40,000 years old. Higham and his colleagues have now begun to find older examples. In November 2011, they announced that they had dated what would become the oldest human fossil in Britain[5]. A fragment of jaw bone had been discovered in 1927 in Kent's Cavern, a coastal cave in Devon, and had been dated in the late 1980s to about 35,000 years old[6].

Higham's team assert that the jaw is more than 41,000 years old[5], on the basis of dates of animal bones excavated above and below the jaw. (The team was unable to date the jaw itself.) Work by Katerina Douka, an archaeological scientist at Oxford (and Higham's partner), published on the same day[7] dated molars from Cavallo Cave in Italy's heel at between 43,000 and 45,000 years old, making them the earliest modern human fossils in Europe, although not everyone agrees that they are human.

"We're starting to build up a picture that modern humans were getting into Europe much earlier than we thought," says Chris Stringer, a palaeoanthropologist at London's Natural History Museum and co-author of the Kent's Cavern paper[5].

"IT JUST BREAKS YOUR HEART TO SEE WHAT PEOPLE HAVE DATED BEFORE."

These early incursions may have put humans in direct contact with Neanderthals who had lived there for millennia. "Getting people up to Kent's Cavern near Plymouth, that's a hell of a thing at 40,000 years ago," says Richard Klein, an archaeologist at Stanford University in California. He doubts that they coexisted for long: "It's hard to imagine they were playing games with Neanderthals when they went up there. They must have replaced them very quickly."

Higham says that his dates tell a more nuanced story. He likens Palaeolithic Europe to a giant chess board, with established Neanderthals facing a series of intrusions by modern humans. In places, the two may have lived alongside each other for thousands of years, opening up the possibility of cultural and even sexual exchanges.

Comparisons of modern human genomes with Neanderthals' suggest that some interbreeding occurred (see page 33). But because Asians and Europeans have identical levels of Neanderthal DNA, geneticists presume that they are seeing the result of trysts that occurred before modern humans moved to Europe. Higham's work could help to pin down when and where humans and Neanderthals were most likely to have interbred.

INVADING EUROPE

Better purification techniques in radiocarbon dating have pushed back the arrival time of the earliest humans in Europe, and could reveal how they crossed paths with Neanderthals.

He thinks that Neanderthals probably went extinct gradually. His work re-dating Neanderthal sites in Croatia[8] and the Caucasus[9] suggests that Neanderthals disappeared from these regions by about 40,000 years ago. Other researchers say that the last Neanderthals may have eked out a living in the Iberian peninsula until as recently as 24,000 years ago[10], although Higham and his former graduate student, Rachel Wood, have unpublished work that questions that timing.

Still, the part of Higham's work that has generated the most debate (or at least the most journal pages), involves the cognitive abilities of Neanderthals. Neanderthals may no longer be written off as knuckle-dragging brutes, but archaeologists disagree over whether Neanderthals were capable of the sort of symbolic representations that underlie language, art and religion.

Shell beads and other ornaments suggest that modern humans made symbolic objects as early as 100,000 years ago in Africa, and probably carried those traditions with them into Europe. Evidence that Neanderthals were capable of symbolic thinking comes partly from what is known as the Châtelperronian industry in central and southeastern France, which included ornamental objects such as perforated animal teeth, shell beads and ivory pendants. Neanderthal bones found alongside such artefacts at the Grotte du Renne in central France made the site "the flagship for the idea that Neanderthals had symbolic behaviour", says Stringer.

Higham, however, questions how good that evidence is[11]. His team dated animal bones, antlers and teeth from various layers of the cave. The dates for those in the Châtelperronian layers were all over the place, from 49,000 to 21,000 years old. Higham thinks that bones and artefacts from different periods have become jumbled, through a combination of geological tumult, excavation errors and shoddy record-keeping. He therefore doesn't think the Châtelperronian objects should be used to support symbolic thinking for Neanderthals.

João Zilhão, a palaeoanthropologist at the University of Barcelona in Spain, has emerged as Higham's staunchest critic. Last year, Zilhão and his colleagues pointed out that the artefacts in the Châtelperronian layer seemed to be in the right place and questioned whether Higham's team had managed to fully decontaminate the bone samples[12]. "How come the bones move and the stone tools do not? It's impossible," he asks. Higham struck back[13], and Zilhão is now drafting another response. "This could go on forever and I've got no more time to spend on it," says Higham.

Both say that their dispute is purely academic. They continue to work together on other material, and are open to collaboration on the Grotte du Renne controversy. "He's pretty easy to work with," Zilhão says of Higham. "He speaks his mind, but so do I."

Stringer says that the understanding of palaeolithic history is in flux. The dates that Higham and others are now generating may settle some long-standing debates, but they are also generating new questions. "Maybe you've got a muddying of the waters before they clarify and settle out," Stringer says.

A CINEMATIC VISION

This summer, Higham will trek to the Denisova cave in southern Siberia's Altai Mountains, to try to make sense of its convoluted history. When Soviet scientists found the cave in the 1970s, they discovered Neanderthal tools and human remains there. But in 2010, DNA sequencing of a finger bone extracted from the cave pointed to the existence of a hitherto unknown population of archaic humans, called Denisovans[14], who lived in the cave sometime between 30,000 and 48,000 years ago[15]. Higham thinks that his team can narrow down that range and perhaps determine whether Denisovans lived in the region with humans and Neanderthals.

Higham's grand vision is to develop a fuller, almost cinematic version of early human migrations. "We want to create this huge map that will allow us to try to look at the movement of people, the movement of objects, the development of new ideas. The big archaeological questions, really." His team has already begun to play around with software capable of building such a map of Europe, some of which incorporates data from a stack of manuscripts on his desk that he hopes will be published over the next year and a half.

But if this film is to be more historical documentary than a period drama, it requires the sort of chronologies that Higham and his team are generating. "You have to know the dates," he says. ■ SEE EDITORIAL P.6

Ewen Callaway *writes for* Nature *from London.*

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